CHAPTER 3. HOIST LOADS

3-1. Hoist Loads due to Flowing Water.

a. Tainter Valves. Three structurally different types of reverse tainter valves (horizontally framed, double skin plate, and vertically framed) have been used in recent designs of lock filling and emptying systems. The horizontally framed valve is desirable structurally but the double skin plate and vertically framed valves are less susceptible to critical hydraulic loads and load variations during the opening cycle.

b. Interpretation of Data. Hoist loads presented herein are the summation of forces on the valve members due to flowing water considered as a single force acting radially at the valve skin plate. Downpull loads act to rotate the valve to the closed position and uplift loads act to rotate the valve to the open position. Basic data were obtained with the valve at fixed positions and under steady-flow conditions. For each valve position, hoist-load data were obtained for a range of velocities under the valve (inflow or outflow divided by total valve opening). For the plots herein, figures 3-3 to 3-6, the velocity under the valve at each valve position was computed (see Appendix B) for different lifts in a specific lock. Table 3-1 gives the relation of velocity under the valve to lift used in plotting the data in figures 3-3 to 3-6.

Table 3-1. Velocity Under Valve, fps

Valve Open Percent	Lift, ft			
	20	40	60	100
0	0.0	0.0	0.0	0.0
10	28.5	41.0	50.0	65.0
20	27.5	39.0	49.0	63.5
30	26.0	37.0	45.5	59.5
40	26.0	37.5	46.5	60.5
50	26.5	39.0	48.5	64.0
60	27.0	40.5	50.0	66.5
70	27.5	40.5	50.5	67.0
80	26.5	39.5	49.0	65.0
90	25.0	37.0	46.5	61.0
100	23.0	34.5	43.0	57.0

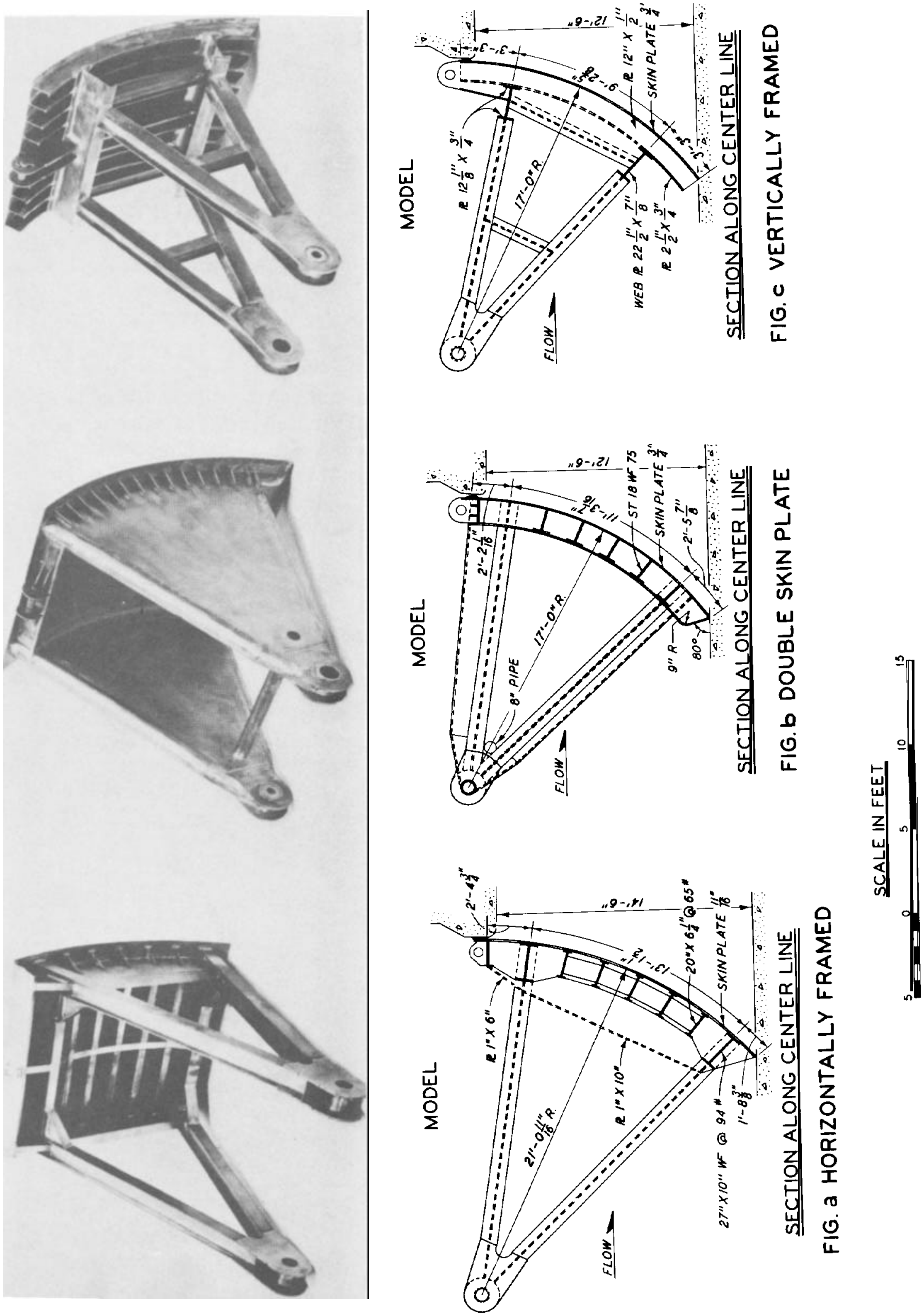


Figure 3-1 tainter type valves

c. <u>Horizontally Framed Valve.</u>

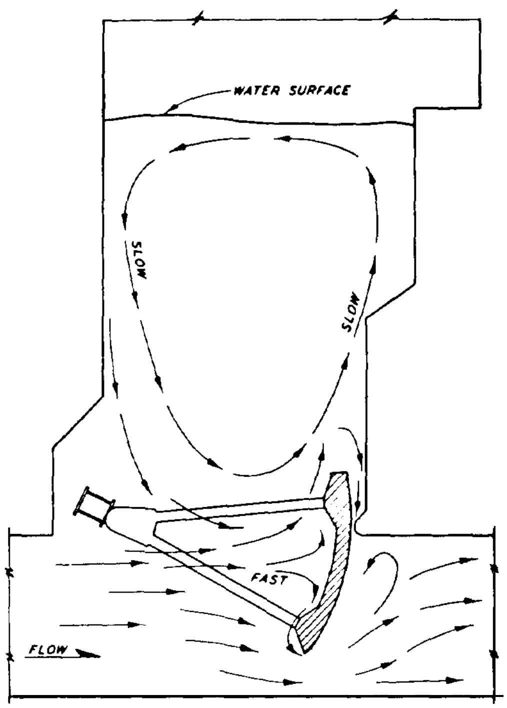
(1) As the name implies, the skin plate is attached directly to a series of horizontal beams and the loads are transmitted to the trunnion arms through vertical frames or girders near the sides of the valve (see fig. 3-1a).

(2) Horizontally framed valves were used almost exclusively in earlier low-lift locks and no inadequacies were indicated until locks in the medium- and high-lift category were required. Serious operational problems with the horizontally framed valve resulting from forces due to flowing water first were encountered in New Lock No. 19, Mississippi River.[f]

(3) During trial operations at New Lock No. 19 it was found that when a valve was at greater than two-thirds angular opening, flowing water caused pulsating loads which were transmitted through the strut and strut arm, resulting in reversal of load on the operating machinery and a consequent severe clattering in the gear train. The pulsations appeared to increase in magnitude with increased valve opening. The resultant loading conditions were of such severity that remedial action was necessary prior to normal operation of the project.

(4) At New Lock No. 19, the lift is 38.2 ft and flow through the culverts is regulated by 14.5- by 14.5-ft reverse tainter valves. The valves are actuated by electric motors through strut-connected mechanical gear systems. Each valve weighs 28,350 lb, with the strut and strut arm adding weights of 3,500 and 3,100 lb, respectively. With a valve submerged in still water, the load on the hoist varied during an opening cycle from about 21 kips (1.45 kips per foot of valve width) near the closed position to about 31 kips (2.14 kips per foot of valve width) near the open position.

(5) Model tests revealed that under normal operating conditions flowing water caused an average load on the hoist in a downpull direction from a gate opening of 0 to about 75% and in an uplift direction from 75 to 100%. Flow approaching the partially open valve divided at the upstream face of the valve with part of the flow going under the valve and part into circulation in the valve well. When this division was above the lower girder, downpull forces prevailed and below the lower girder, uplift forces occurred. Flow patterns in the valve well during downpull and uplift conditions are shown in figure 3-2. Also, it was revealed that random variations in hoist load increased as the valve opening increased. With the valve near the open position, loads



CONDITION AT WHICH DOWNPULL OBTAINS

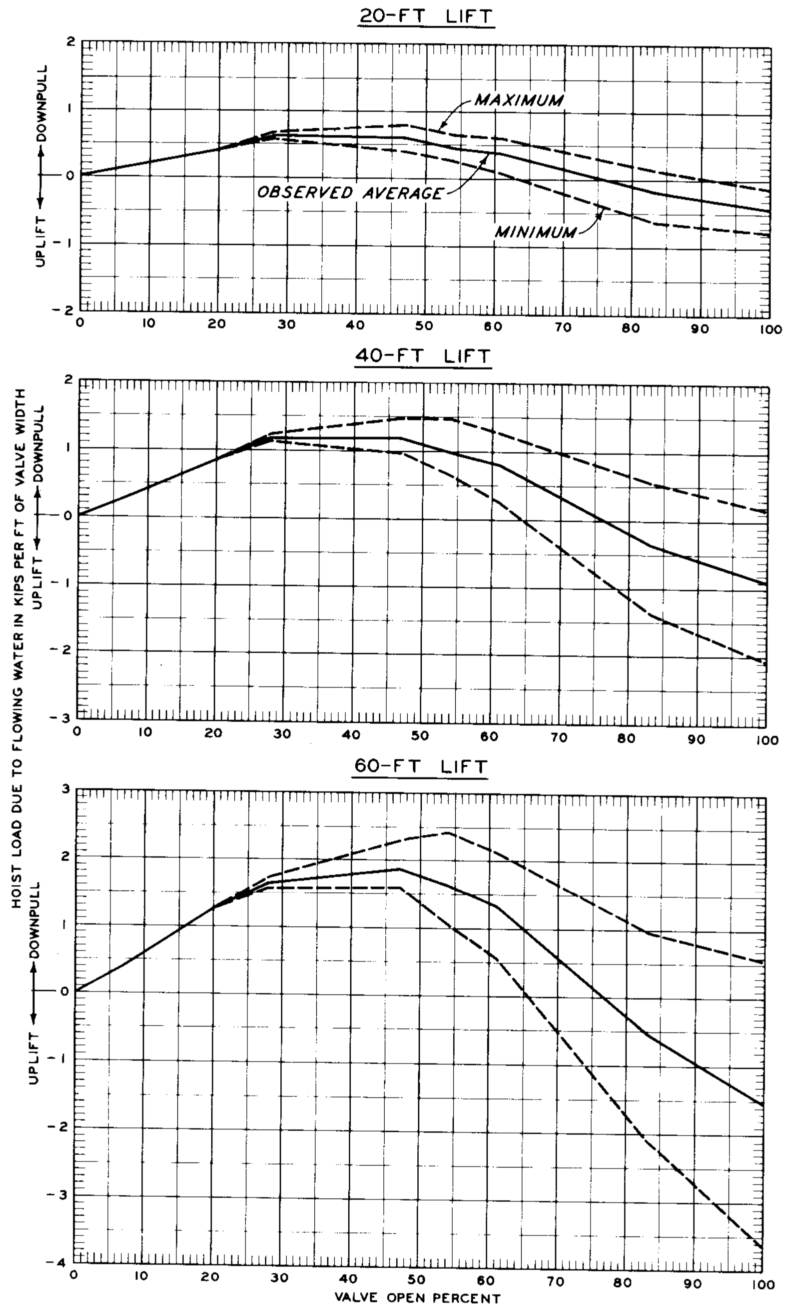
CONDITION AT WHICH UPLIFT OBTAINS

Figure 3-2. Currents in valve recess

on the hoist due to flowing water varied from 12 kips (0.83 kips per foot of valve width) downpull to 48 kips (3.31 kips per foot of valve width) uplift. Thus, with the submerged valve exerting a downpull load of only 31 kips on the valve hoist, it is obvious why severe clattering resulted in the gear train.

(6) Hoist loads due to flowing water obtained in a 1:12-scale model of the valve shown in figure 3-1a at lifts of 20, 40, and 60 ft are plotted in figure 3-3. For planning purposes, these data are considered generally applicable and the prediction of total loads for similar valves based on the width of the valve is justified by the fact that tests have revealed that modifications to valve members above the lower girder have a very small effect on hoist loads. Thus, the height of the valve has a negligible effect on hoist loads except as it modifies the velocity of approach and this is accounted for by plotting valve opening as a percentage of total opening rather than as a specific dimension.

(7) Modifications to the lower girder and the portion of the valve below the girder can have a material effect on valve loads.[f,g] For



(SEE PARAGRAPH 3-1b)

Figure 3-3. Hoist loads, horizontally framed valve instance, installation of a cover plate from the valve lip to the flange of the lower girder resulted in a 30% increase in peak downpull but a 35% decrease in both peak uplift and load variation.

d. Double Skin-Plate Valve.

(1) With the objective of presenting a smooth upstream surface to flow, instead of the projecting edges of the horizontal beams, the transverse beams are covered with a smooth, curved skin plate which results in a streamlining effect (see fig. 3-lb). The inside plate adds rigidity to the leaf and can be utilized in the stress analysis. It is customary to use welded construction, making the tank watertight. Thus, the valve can be operated with the tank filled with air, provided the valve has sufficient weight to counteract its buoyancy as well as the dynamic hydraulic uplift forces. In most instances, however, greater stability is needed and the tank is filled with water and a rust-inhibiting fluid.

(2) General design values of hoist loads due to flowing water obtained in a 1:15-scale model of the valve shown in figure 3-lb at lifts of 20, 40, 60, and 100 ft are plotted in figure 3-4. Results of other tests on valves of this type are given in references a, d, i, j, and k.

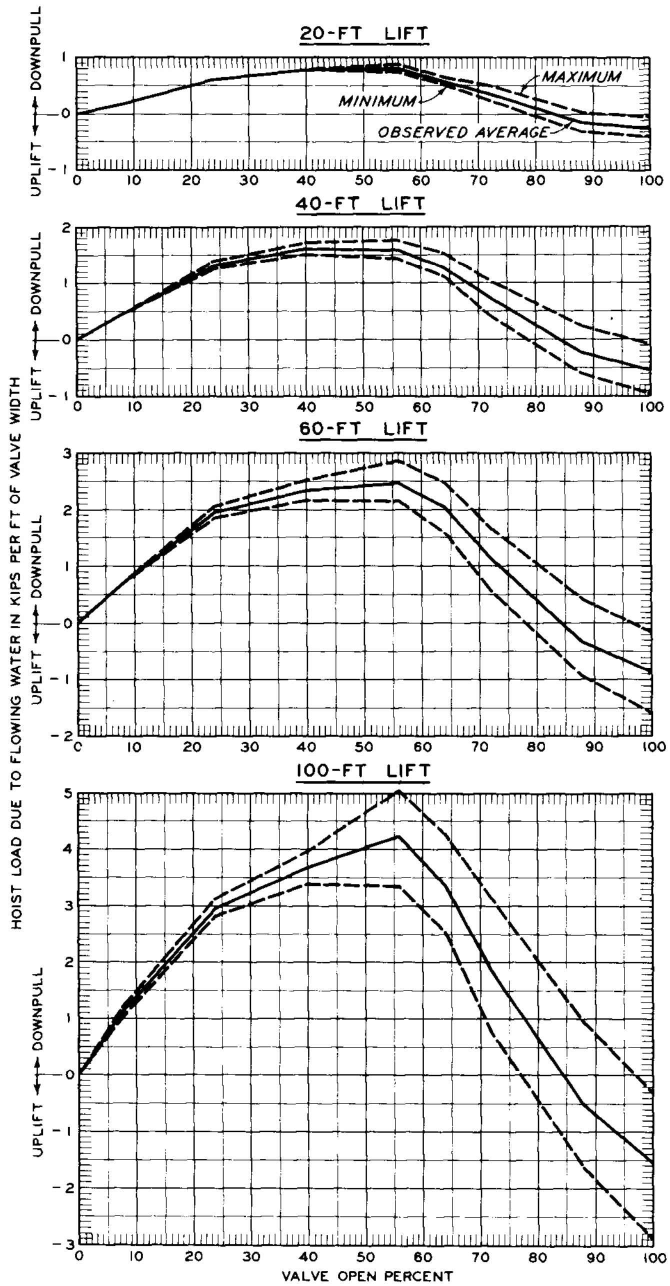
e. Vertically Framed Valve.

(1) In valves of this type the skin plate is attached to a series of curved T-beam ribs along parallel vertical planes (see fig. 3-1c). The water loads are transmitted to the trunnion arms through horizontal girders welded to the outer flanges of the ribs. Thus, open spaces where water can circulate freely are provided between the ribs, and between the skin plate and the horizontal girders.

(2) General design values of hoist loads due to flowing water obtained in a 1:15-scale model of the valve shown in figure 3-1c at lifts of 20, 40, 60, and 100 ft are plotted in figure 3-5. The flanges on the T-beam ribs that transmit loads from the skin plate to the horizontal girders must be narrow. Flanges 2.5 in. wide were suitable in the example valve, but flanges 12 in. wide inhibited the desired circulation and were very detrimental to loading characteristics. Results of an additional test on a valve of this type are given in reference g.

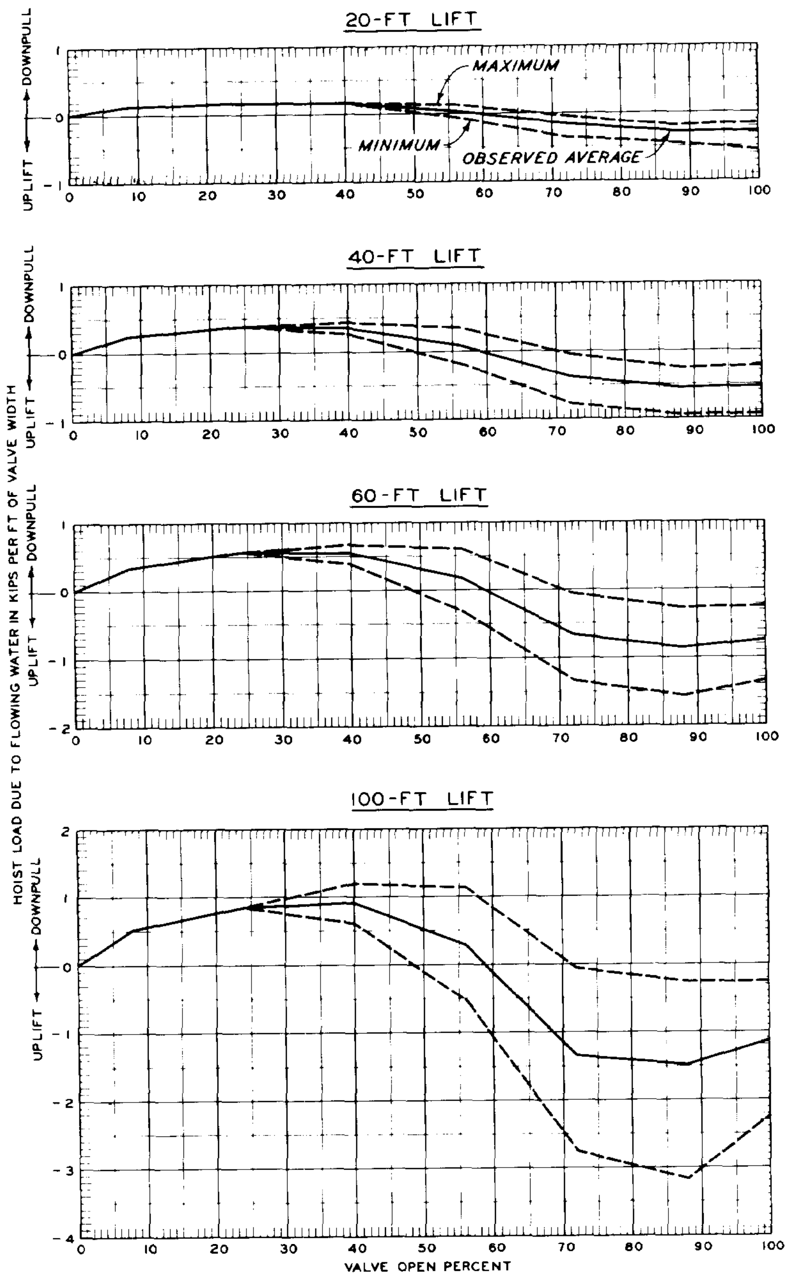
f. General Comments.

(1) Average loads and maximum load variations for the three valves shown in figure 3-1 at a 6O-ft lift are plotted in figure 3-6 to show the relative load characteristics of each valve.



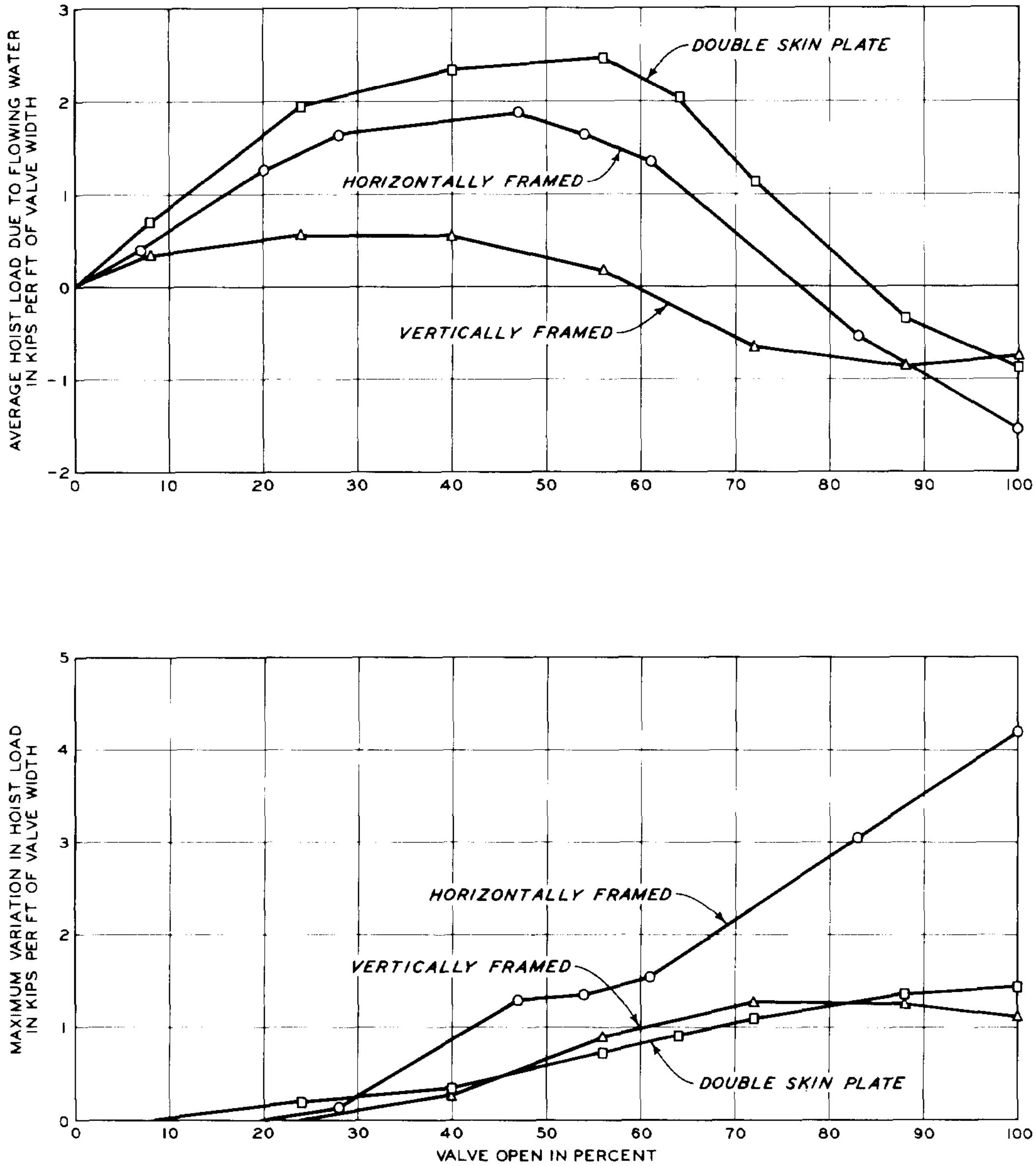
(SEE PARAGRAPH 3-1b)

Figure 3-4. Foist loads, double skin-plate valve



(SEE PARAGRAPH 3-1b)

Figure 3-5. Hoist loads, vertically framed valve



(SEE PARAGRAPH 3-1b)

Figure 3-6. Hoist loads, 60-ft lift

(2) For all three types of valves the two features that most affect loads on the valve hoist due to flowing water are the depth of the lower girder and the extension of the lower lip of the skin plate below the lower girder. A decrease in the depth of the lower girder results in a decrease in peak downpull and load variations and, also, a decrease in the range of valve positions at which downpull occurs and an increase in the range of positions at which uplift occurs. Data are not conclusive as to whether peak uplift is decreased. An increase in the extension of the lower lip of the valve below the lower girder decreases peak downpull and the range of valve positions at which downpull occurs but increases peak uplift and the range of valve positions at which uplift occurs. Load variations remain essentially unchanged.

(3) The effect of load reversals on the valve hoist was demonstrated dramatically at New Lock No. 19 by the severe clattering in the mechanical gear system. When operation is directly from a hydraulic piston, load reversals are not readily noticeable. However, these load reversals still are very undesirable as they are likely to result in excessive wear in the strut connections and could cause other structural damage.

(4) It should be apparent to the designer that consideration of a horizontally framed valve should be limited to locks with lifts of no more than about 30 ft. When designed for equal lifts, the double skin-plate valve usually will be heavier and, particularly if the tank is filled with a rust inhibitor, will require greater hoist capacity than will the vertically framed valve. However, some designers consider a heavy valve to be more stable and thus worth the cost of the additional hoist capacity. Certainly the double skin-plate valve can be used successfully at all lifts. The vertically framed valve probably has economic advantages over the double skin-plate valve and is being used with no problems at the 63.6-ft lift Holt Lock. If this valve is considered for a lock with a very high lift, excess weight may be required to prevent load reversals on the valve hoist.

3-2. Total Hoist Loads. In determination of total hoist loads, the designer must combine the loads due to flowing water (discussed in paragraph 3-1) with loads resulting from: (a) weight of the submerged valve, (b) weight of the operating stem, (c) friction at the side seals and in the trunnion, and (d) head differentials across the top seal (paragraphs 4-4 and 4-4a).

3-3. Peak Head Across Valve.

a. Near the beginning of a filling or emptying operation if a failure of the hoisting mechanism should allow a valve to slam shut, a head across the valve considerably larger than the difference between upper and lower pool would result. Time-history of pressures on each side of the valve can be developed from available formulas concerned with surges and water hammer. Pressure oscillations on each side of the valve will occur with decreasing amplitudes through several cycles. However, the periods of these oscillations are likely to be different on the two sides of the valve; and although individual peaks (positive and negative) on each side of the valve probably will occur during the first cycle, it is possible that the maximum head across the valve will occur later and be less than the difference between the first cycle peaks. Also, there are likely to be reversals in the head across the valve.

b. In a reverse tainter valve installation, the valve well would serve as a surge chamber and thereby delay and reduce the buildup of pressure on the high-head side of the valve. Although the surge in the valve well would spill out at the top of the lock wall the pressure on the valve would result from forces causing flow up the well and could be considerably greater than the difference between the top of the wall and the valve. If the valve is not vented, the pressure on the low-head side of the valve could drop quite rapidly to about -33 ft (one atmosphere negative); with a vented valve, the pressure would drop to essentially atmospheric.

c. Sudden closure of a valve due to breakage of the hoisting mechanism is very unlikely to occur and usually is not considered a design condition. On the other hand, operation that would produce surges is most probable. For many reasons the operator may reverse the valves during or immediately after the opening cycle. A series of tests was conducted in the Cannelton Lock model[1] during which the 18-ft-high by 16-ft-wide filling valves were opened at a rate to reach fully open in 2 min. Immediately upon reaching l/2, 3/4, and then fully open, the valves were reversed and closed at the same rate. The surges generated produced a peak head differential across the valve of about 1.5 times the initial lift.

d. The conditions of peak head across the valve to be used in the structural design should depend on the local situation and judgment on the part of the designers. Certainly all designs must provide for the head created by the abnormal operation described in paragraph 3-3c. The hydraulic designer should describe the possible loadings that could result from operational and accidental closure of the valves during a filling or emptying operation.